Designing for Tsunamis
Background Papers

A multi-state mitigation project of the National Tsunami Hazard Mitigation Program (NTHMP)

National Oceanic and Atmospheric Administration (NOAA)
U.S. Geological Survey (USGS)
Federal Emergency Management Agency (FEMA)
National Science Foundation (NSF)
State of Alaska
State of California
State of Hawaii
State of Oregon
State of Washington

March 2001

Designing for Tsunamis
Background Papers

A multi-state mitigation project of the National Tsunami Hazard Mitigation Program (NTHMP)

National Oceanic and Atmospheric Administration (NOAA)
U.S. Geological Survey (USGS)
Federal Emergency Management Agency (FEMA)
National Science Foundation (NSF)
State of Alaska
State of California
State of Hawaii
State of Oregon
State of Washington

Funding for this project was provided by the U.S. Department of Commerce and the National Oceanic and Atmospheric Administration (NOAA).

March 2001

CREDITS

PROJECT MANAGER

On behalf of the National Tsunami Hazard Mitigation Steering Committee

Richard Eisner
Regional Administrator
State of California
Governor's Office of Emergency Services

CONSULTING TEAM

J. Laurence Mintier
Rik Keller
J. Laurence Mintier & Associates

L. Thomas Tobin
Tobin & Associates

Robert A. Olson
Robert Olson Associates, Inc.

Bruce Race
RaceStudio

Jeanne Perkins
Association of Bay Area Governments

GRAPHICS

Daniel Jansenson
Daniel Jansenson Architect

EXPERT ADVISORS PANEL

James E. Russell
Building Code Consultant

Robert L. Wiegel
Department of Civil and Environmental Engineering
University of California-Berkeley

Mark R. Legg
Legg Geophysical

Costas E. Synolakis
Department of Civil Engineering,
Tsunami Research Group
University of Southern California

NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM (NTHMP) STEERING COMMITTEE

Chairperson

Eddie Bernard
NOAA/PMEL

NOAA

Frank Gonzalez
PMEL

Richard Hagemeyer
NWS Pacific Region

Richard Przywarty
NWS Alaska Region

Charles McCreery
Pacific Tsunami Warning Center

Tom Sokolowski
West Coast and Alaska Tsunami Warning Center

FEMA

Michael Hornick
NFIP, Region IX

Chris Jonientz-Trisler
Earthquake Program, Region X

USGS

David Oppenheimer

Craig Weaver
National Earthquake Hazards Reduction Program

NSF

Clifford Astill
Civil and Mechanical Systems Division

Alaska

Gary R. Brown
Alaska Division of Emergency Services

Roger Hansen
Geophysical Institute, University of Alaska

R. Scott Simmons
Alaska Division of Emergency Services

California

Lori Dengler
Department of Geology, Humboldt State University

Richard Eisner
Governor's Office of Emergency Services

Hawaii

Laura Kong
Hawaii Division, USDOT, FHWA

Brian Yanagi
State of Hawaii Civil Defense Division

Oregon

Mark Darienzo
Oregon Emergency Management

George Priest
Oregon Department of Geology and Mineral Industries

Washington

George Crawford
Washington State Military Department, Emergency Management Division

Timothy Walsh
Division of Geology and Earth Resources

ACKNOWLEDGEMENTS

We greatly appreciate the contributions and review comments from the following individuals:

Alaska

Bob Bright, Community Development Director
Kenai Peninsula Borough

Linda Freed, City Manager
Eileen Probasco, Planner
City of Kodiak

Scott Janke, City Manager
Rachel James, Planning Technician
City of Seward

Carol Smith, Acting Director/Planning Technician
Community and Economic Development Department
City of Valdez

California

Tina Christiansen, Director
Werner Landry, Senior Engineering Geologist
Planning and Development Review Department
City of San Diego

Don Olson, Director
Barbara Shelton, Environmental Analyst
Community Development Department
City of Santa Barbara

Ernest Perry, Community Development Director
Del Norte County

Hawaii

Dee Crowell, Director
Keith Nitta, Planner
Planning Department
County of Kauai

Virginia Goldstein, Director
Rodney Nakano, Planning Program Manager
Planning Department
County of Hawaii

Oregon

Rainmar Bartl, City Planner
City of Cannon Beach

Washington

Ken Kimura, Director, Planning Division
Department of Public Services
Grays Harbor County

Connie J. Manson, Senior Library Information Specialist
Lee Walkling, Library Information Specialist
Washington Department of Natural Resources
Division of Geology and Earth Resources

Other

Alan L. Yelvington, Project Officer
U.S. Coast Guard

TABLE OF CONTENTS

INTRODUCTION

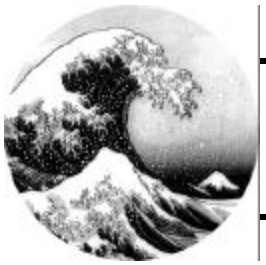
The following seven background papers provide supporting information for the report *Designing for Tsunamis: Seven Principles for Planning and Designing for Tsunami Hazards*. *Designing for Tsunamis*, intended for use primarily by local government officials, sets out guidelines for mitigating tsunami risk through land use planning, site planning, and building design.

Background Paper #1, *Understanding the Tsunami Risk*, is intended to help guidelines users understand the source and nature of tsunamis and how a tsunami may affect their community. Background Paper #2, *Local, State, and Federal Framework for Land Use Planning and Coastal Development*, describes the planning/regulatory context for the mitigation measures discussed in the guidelines.

Background Papers #3, #4, and #5 discuss approaches to addressing the tsunami hazard and identify mitigation measures at three levels within the land use planning/development regulation hierarchy. Background Paper #3, *Land Use Planning*, discusses mitigation planning at the broadest level in local government—the local comprehensive plan. Background Paper #4, *Site Planning*, discusses the application of mitigation techniques through design review and approval of individual projects. Background Paper #5, *Building Design*, discusses how tsunami hazards can be mitigated through building design.

Background Paper #6, *Infrastructure and Critical Facilities*, explores how these special types of development can or should be treated within the land use planning/development regulation hierarchy.

Finally, Background Paper #7, *Vertical Evacuation*, looks at how the strategy of moving at-risk populations to upper floors of buildings might influence development siting and building design.



BACKGROUND PAPER #1: UNDERSTANDING THE TSUNAMI RISK

INTRODUCTION

This background paper describes the nature and effects of tsunamis as a foundation for mitigation efforts by users of the guidelines—local government staff and officials and other people involved in comprehensive planning, zoning, building regulation, and development-related activities.

Tsunami risk is a function of three factors: 1) the nature and extent of the tsunami hazard; 2) the vulnerability of facilities and people to damage; and 3) the amount of development or number of people exposed to the hazard.

Tsunamis are natural events that can alter the landscape and destroy human settlements, infrastructure, and economic activity. Communities may be vulnerable because of the location and quality of the built environment. The principal exposure will be people, buildings, and infrastructure located in the low-lying potential tsunami inundation area. Locally-generated tsunamis preceded by earthquake groundshaking may result in tsunami losses in the low-lying coastal areas in addition to building and infrastructure damage throughout the area due to strong shaking and possible soil failure.

While the guidelines and these background papers provide general information, local policy decisions and the application of the information should be based on the results of specific tsunami hazard studies so the local potential of inundation is well understood. Appended to this paper is a suggested scope of work for a local tsunami hazard study (see Appendix 1-1: Suggested Contents of a Tsunami Hazard Study).

KEY CONCEPTS AND FINDINGS

This background paper presents two key concepts. They are intended to facilitate users' understanding of tsunamis and community risk so locally-appropriate and practical loss prevention programs and measures can be initiated by applying the guidelines and the advice contained in the other background papers.

Concept 1: Understand Your Community's Tsunami Risk

Effective mitigation measures are based on an understanding of the risk faced by a community. This background paper describes tsunami risk on a broad scale, but it is no substitute for a local evaluation of the hazard and community vulnerability.

Principal considerations in such evaluations include:

- Understanding that natural hazards are ever-present, but catastrophic incidents are rare for individual localities;
- Using local vulnerability studies to design specific loss prevention measures and programs; and
- Knowing that in the aftermath of major damaging events, people will frequently assign blame to those they believe are responsible for not taking precautionary actions.

The waterfront area of Crescent City, California, flooded by the 1960 tsunami.
Credit: USGS

Concept 2: Acquaint Community Officials and Leaders with the Community's Tsunami Risk

People are preoccupied with relatively immediate issues and decisions. The mitigation of risk from natural hazards requires a long-term and sustained commitment, the benefits of which may not be visible for decades. Regardless, mitigation practices should be built into ongoing programs, procedures, and processes to assure that tsunami risk is managed on a regular basis.

Important considerations include:

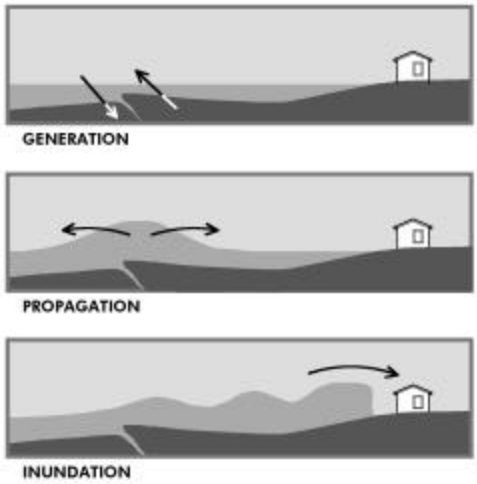
- Making special efforts to regularly inform key officials and community leaders about risk and the status of mitigation;
- Mobilizing community interest and support for mitigation through effective means;
- Assembling example materials from other threatened communities and states to demonstrate what others are doing and to adapt it for local application; and

- Designing community-based mechanisms, such as task forces and committees, to maintain a focus on risk mitigation measures.

HAZARD DESCRIPTION

Tsunami Definition

A tsunami is a series of long waves generated by any sudden displacement of a large volume of water. Tsunamis are triggered by submarine earthquakes, submarine volcanic eruptions, underwater landslides or slumps of large volumes of earth, meteor impacts, and even onshore slope failures that fall into the ocean or a bay. Tsunami waves can propagate as a series of long waves across entire ocean basins. The hazard can last for many hours as the tsunami passes, and waves may resonate in some harbors and bays for days after the initial attack. For example, tsunamis from the 1960 offshore Chile event were recorded for more than one week in some locations.



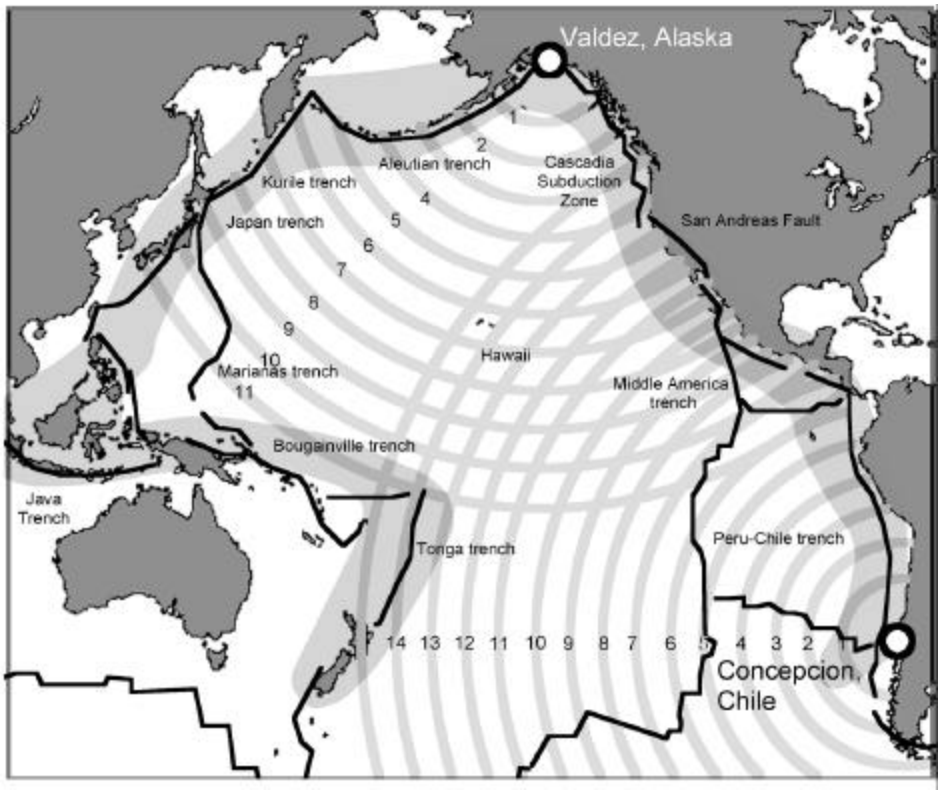
A tsunami is a series of deep, long waves
Generated by a sudden displacement of a large volume of water.

Seiches (or harbor oscillations) are a related hazard for enclosed bays, inlets, and lakes. Alaska and parts of Washington and British Columbia, in particular, have numerous communities vulnerable to such events. These destructive tsunami-like waves can be generated by earthquake motions, subsidence or uplift of large blocks of land, submarine and onshore landslides, sediment failures, and volcanic eruptions. Large tidal bores, strong currents, and the interaction of ocean swells and surf outside of bays and inlets may amplify the waves. The strong currents associated with these events may be more damaging than inundation by waves.

Source Zones

Tsunamis are associated primarily with seismic activity. The Pacific "Ring of Fire," one of the most active seismic features on earth, circles the Pacific Ocean from the southern tip of Chile,

north along the west coasts of both South and North America, turning west along the Aleutian Islands arc of Alaska, and south through Japan, the Philippines, and the eastern Indo-Pacific region. Occasionally, tsunamis generated within this region threaten almost every island and coastal settlement in the Pacific Rim, including those in the five Pacific states: Alaska, California, Hawaii, Oregon, and Washington.



The Pacific "Ring of Fire" is the most active seismic feature on earth. Tsunami waves triggered by seismic activity can travel across the Pacific Ocean at up to 500 miles per hour, striking distant coastal areas in a matter of hours. The figure shows the estimated number of hours for tsunami-generated waves to travel across the Pacific Ocean from Alaska and Chile, respectively.

While not on the Ring of Fire, Hawaii sits in the center of a tectonic hot spot. Earthquakes and large landslides along the flanks of Hawaii, associated with the injection of magma into volcanoes' "plumbing systems," have generated tsunamis. In some areas, the risk of tsunamis from landslides may be greater than that posed by offshore earthquakes. Some locations, like parts of Alaska and Hawaii, may be stricken by multiple tsunamis from different sources such as volcanic eruptions, submarine earthquakes, and landslides, which may occur at the same time, greatly compounding the hazard.

Local and Distant Sources of Tsunamis

Tsunamis are typically classified as either local or distant. These two types of tsunamis have different implications for comprehensive planning; zoning; building siting, design, and construction activities; and evacuation warning. For example, local tsunamis likely will follow associated earthquake groundshaking and possibly ground failures that may produce additional damage. Evacuation will have to be nearly instantaneous when responding to local tsunamis, but assuming effective warning systems exist, many hours may be available to evacuate people from exposed areas before distantly-generated tsunami waves arrive.

Tsunamis from Local Sources

Tsunamis from local sources usually result from earthquakes occurring off nearby coasts. In the Pacific Northwest, including Alaska, these typically involve large subduction earthquakes in the Cascadia Subduction Zone or the Alaskan-Aleutian Subduction Zone. The Cascadia zone, where the Farallon (or Gorda or Juan de Fuca) Plate is sliding beneath the North American Plate, lies approximately 60 miles (100 kilometers) seaward of Cape Mendocino, California, and extends north along the coasts of Oregon, Washington, and British Columbia to the Queen Charlotte Islands. The Alaskan-Aleutian zone, where the Pacific Plate is sliding beneath the North American Plate, extends from southeastern Alaska to the westernmost tip of the Aleutian Islands.

Along active subduction coasts, tsunamis may also be generated by large landslides, both submarine and above water, into coastal waters (e.g., Lituya Bay, Alaska), and by volcanic activity (e.g., Krakatoa, Indonesia), especially along the Aleutian volcanic island chain.

In Hawaii, two of the largest tsunamis in the historic record (1868 and 1975) were caused by normal-fault earthquakes on the flank of the island. A few other much smaller Hawaii tsunamis may have been caused by onshore or submarine landslides. Volcanic activity is associated with these events such as the eruptions of Kilauea in 1975. Although explosive volcanic eruptions are uncommon in Hawaii, such activity does occur and may trigger local tsunamis.

In California south of the Cascadia Subduction Zone, local tsunamis may be generated by large offshore or coastal fault movements. Some parts of the coast are cut by active reverse and thrust faults, which push up the coast or offshore ridges during large earthquakes. Other parts are dominated by strike-slip faulting, where large areas of seafloor uplift or subsidence occurs due to local irregularity in the fault trends. In southern California, large submarine landslides along the steep and unstable slopes of the continental shelf edge and offshore borderland ridges can generate locally-destructive tsunamis for the adjacent coastal areas.

The travel time for a locally-generated tsunami, from initiation at the source to arrival at coastal communities may be within five to 30 minutes. For example, a series of destructive tsunamis began striking coastal communities on Okushiri Island, Japan, about eight minutes after the July 12, 1993, Hokkaido-Nansei-Oki earthquake mainshock. At least one village was hit by tsunami waves estimated to be 12 meters high (39.5 feet) while waves at other locations were between five and ten meters high (about 16.5 to 33 feet). Located almost directly above the epicentral area, the island received tsunami warnings about five minutes after the earthquake, about the best

warning time possible with present technology. Fortunately, casualties were limited because people fled to evacuation sites on higher ground immediately after feeling the earthquake without waiting for an official warning. Public information and training programs were effective in reducing losses from this event.

Tsunamis from Distant Sources

Tsunamis from distant sources are the most common type observed along the Pacific Coast of the United States. Large tsunamis generated anywhere around the Pacific "Ring of Fire" propagate across the ocean with little energy loss before striking populated U.S. coastlines. The Pacific states may suffer both regional and Pacific-wide tsunamis. By definition, regional tsunamis affect smaller areas than Pacific-wide tsunamis, either because the energy released is of insufficient magnitude for Pacific-wide propagation or because the geographical configuration of the source area restricts the tsunami's spread. The combined impacts of the earthquake and regional tsunami that originated off the Philippine Islands on August 16, 1976, killed approximately 8,000 people in the affected area. Regional destructive tsunamis within the Sea of Japan in 1983 and 1993 were unable to propagate out into the larger Pacific Ocean basin.

Pacific-wide tsunamis, although less frequent than regional tsunamis, have greater destructive potential because the waves are larger, travel farther, and affect broader coastal areas. The time required for a distant tsunami to reach the Hawaiian and mainland coasts will vary between approximately 5½ to 18 hours, depending upon the tsunami's place of origin. The effects of a distant tsunami on a coastal area may be negligible or severe depending upon the magnitude of the tsunami, its source distance, and its direction of approach. For example, the tsunami generated by the May 22, 1960, Chile earthquake spread death and destruction across the Pacific Ocean from Chile to Hawaii, Japan, and the Philippines. The coastal and offshore source zone measured about 135,000 square miles (approximately 218 miles by 622 miles), nearly the same area as the state of California. The length of the fault rupture may have reached 750 miles. As a result, over 2,000 fatalities occurred in Chile, due mostly to the tsunami. Losses also were severe in Hilo, Hawaii (61 fatalities and 282 serious injuries), and in Japan (122 fatalities). In contrast, Kodiak Island, Alaska, noted less than one meter rise in the water level, and losses in California were mainly in harbors where strong currents smashed, sank, or grounded small craft, and damaged dock facilities.

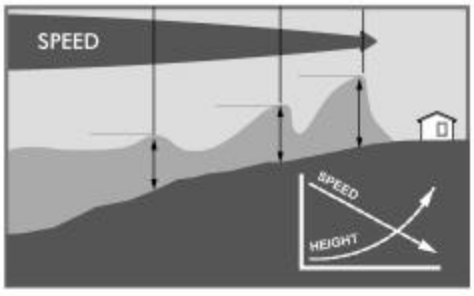
Tsunamis generated by the March 28, 1964, Alaskan earthquake caused both distant and local impacts, including losses in all five Pacific states, as well as other Pacific Rim countries. Alaska suffered 106 fatalities and over $84 million in damage, but in Hawaii, compared to the 1960 Chilean event, damage was minimal. In contrast, Crescent City, California, suffered ten fatalities and over $7 million in damage, and Kodiak Island, Alaska—one of several Alaskan cities and communities to suffer losses—experienced land subsidence of about 6.5 feet followed by ten waves that contributed to the destruction of about 80 percent of the industrial and commercial areas and killed 15 people. Kodiak's bedrock location limited earthquake shaking damage to only minor losses. Valdez, Alaska, experienced submarine landslides and local tsunamis where the highest wave reached 23 feet, destroying much of the town. Consequently, Valdez was rebuilt at a higher elevation to minimize future tsunami damage. Seward, Alaska, experienced

tsunamis 30 to 40 feet high due to both fault rupture and local submarine landslides, causing extensive damage to the docking areas and fires in petroleum storage facilities.

Tsunami Characteristics

Tsunamis travel outward from the source area and may be highly directional. For example, for an earthquake-generated tsunami, most of the energy propagates at right angles away from the long axis of the source fault rupture. The wave speed depends on the water depth, undergoing accelerations and decelerations as the ocean bottom depth varies. Such wave speed changes cause the wavefronts to bend (refract), creating area where the energy is focused (wave height increases) and defocused (wave height decreases). In the open ocean, wave speeds may reach 500 miles per hour (800 kilometers per hour)—as fast as a jet airplane—with the distance between successive crests (wavelength) often exceeding 100 miles. Wave heights in deep water may be only a few feet high, and due to their long wavelength, produce only a gentle rise and fall of the sea surface that is usually unnoticed.

As a tsunami enters the shoaling waters near the coast, its wave speed diminishes, its wavelength decreases, and its height increases, often greatly. The first wave may not be the largest, with the initial wave typically being followed by several larger and more destructive waves. Even though the waves slow upon reaching the coastline, they still travel faster than Olympic long-distance runners—faster than 15 miles per hour.



As a tsunami approaches shore, it slows down and dramatically increases in height.

The configuration of the coastline, the shape of the ocean floor, and the characteristics of the advancing waves play important roles in the potential for destruction. For islands, no matter from which direction the tsunami arrives, all sides usually will be affected. As the wave wraps around the island, the height or run-up may be small at many points along the coast, but increases greatly where the two opposing wavefronts meet on the backside of the island. Focusing effects due to the wavefront bending on irregular coasts may also result in locally high wave amplification. Bays, sounds, inlets, rivers, streams, offshore canyons, islands, and flood control channels may cause various effects and result in greater damage than many people would expect. It has been estimated, for example, that a tsunami wave entering a Southern California flood control channel could reach a mile or more inland, especially if it enters at high tide. Offshore canyons can focus tsunami wave energy and islands can filter the energy. The orientation of the coastline determines if the waves strike head-on or are refracted from other parts of the coastline.

Unlike earthquake shaking where damage may occur over large areas in the source region—hundreds of square miles in many cases—tsunamis impact long, low-lying stretches of linear coastline, extending inland for relatively short distances. After striking a coast, the wave reflects back to sea, but may also be reflected back to the coast again and again from offshore islands or submerged ridges, banks, and shelves, as a series of waves.

Rather than rising water, the first visible indication of an approaching tsunami could be receding water (drawdown) caused by the wave trough preceding a large inbound wave crest. Rapid drawdown creates strong currents in harbor inlets and channels that can damage coastal structures due to erosive scour, such as around piers and pilings. As the water's surface drops, piers can be damaged by boats or ships straining at or breaking their mooring lines. The vessels can overturn or sink due to strong currents, collision with other objects, or impact with the harbor bottom.

Conversely, a rise in water level may be the first indication of a tsunami. The advancing tsunami may initially resemble a strong surge increasing the sea level like the rising tide, but the tsunami surge rises faster and does not stop at the shoreline. Even if the wave height appears to be small, for example, three to six feet, the strength of the accompanying surge can be deadly. Waist-high surges can cause strong currents that float cars, small structures, and other debris. Boats and debris are often carried inland by the surge and left stranded when the water recedes. Outflow following inundation also creates strong currents, which rip at structures and pound them with debris, and erode beaches and coastal structures.

Moreover, under certain conditions the crest of an advancing wave may overtake the preceding trough while some distance offshore, causing the wave to proceed shoreward as a "bore" with a churning front. The bore phenomenon resembles a step-like rise in the sea level that advances rapidly (from 10 to 60 miles per hour). Normal tidal bores at the Bay of Fundy, Canada, or the Yellow River, China, provide examples of this phenomenon.

The force and destructive effects of tsunamis should not be underestimated. At some locations the advancing turbulent wave front will be the most destructive part of the wave. In other situations, the greatest damage may be caused by the outflow of water back to the sea between crests, sweeping all before it and undermining roads, buildings, bulkheads, and other structures. This outflow action can carry enormous amounts of highly damaging debris with it, resulting in further destruction. Ships and boats, unless moved away from shore, may be dashed against breakwaters, wharves, and other craft, or be washed ashore and left grounded after the seawater recedes.

FACTORS UNIQUE TO TSUNAMI RISK MANAGEMENT

Coastlines have always been a favored location for human settlements. Attractive coastal locations and a growing affluent population have combined to increase development of housing, maritime facilities, and resorts in coastal communities in recent times. Long gaps between devastating tsunami events (and apparent disregard of more frequent hazards such as strong storms, sea level changes, and coastal erosion) have produced a coastal population that seems to ignore the destructive tsunami threat. According to one recent estimate, 489 cities in Alaska,

California, Hawaii, Oregon, and Washington are susceptible to tsunami inundation, with an estimated 900,000 people living or working within areas that could be inundated by a 50-foot tsunami.

Table 1-1.
Potential Destructiveness of Tsunamis in the Five Pacific States

State	Cities susceptible to tsunamis	Population endangered by a 50-foot tsunami
Washington	102	96,000
Oregon	60	31,500
California	152	589,500
Hawaii	123	131,000
Alaska	52	47,000
Total	**489**	**895,000**

Source: TsuInfo Alert, v.2, no. 2, March-April 2000. Terry Wallace, University of Arizona, Department of Geosciences.

Mainland coastal states and Hawaii have several unique factors that affect the siting of development and design of buildings. Recently prepared maps for several locations show potential tsunami inundation areas along different types of coastlines. Important factors affecting tsunami exposure include:

- All or parts of the mainland states are located near active subduction zones (Cascadia and Alaska-Aleutian) or other well-defined tsunami-producing zones. Local tsunamis generated by these zones will reach the coasts extremely quickly (within 5-30 minutes, depending on the distance to the zones).

- Strong earthquakes, whether accompanied by tsunamis or not, are rare events in most low-lying coastal communities. With little strong groundshaking experience, these communities have little awareness of earthquake hazards. Yet even with minimal earthquake activity, the risk of damage from a major tsunami is considered high for these communities.

- Except in Hawaii and a few mainland coastal communities, tsunami awareness is not currently embedded in coastal community "culture."

- Coastal communities vary in size, but with some notable exceptions, such as Los Angeles, Honolulu, Santa Barbara, San Francisco, and San Diego, most communities are relatively small.

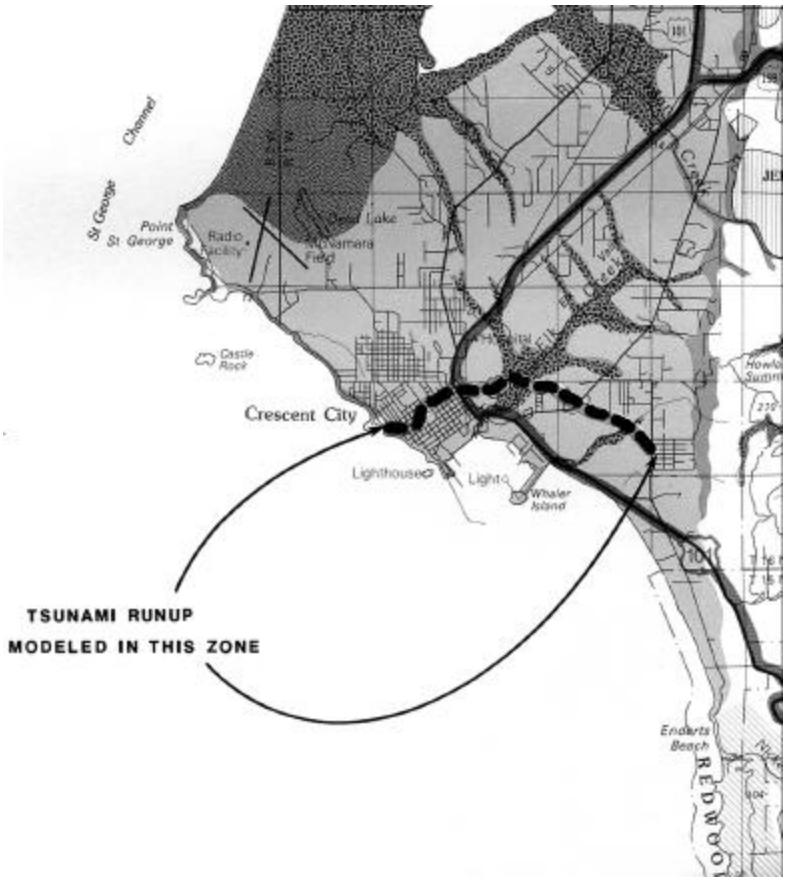
- Many coastal communities are largely recreational, having many short-term and seasonal visitors. This presents a special problem as losses could be very high if a destructive tsunami occurred at a seasonal peak population time.

Case Study: Planning Scenario For Humboldt and Del Norte Counties

In 1995, the California Division of Mines and Geology published Special Publication 115, entitled *Planning Scenario in Humboldt and Del Norte Counties, California for a Great Earthquake on the Cascadia Subduction Zone*. This report includes a description with supporting maps of the potential effects of a tsunami on the cities of Eureka (Humboldt County) and Crescent City (Del Norte County). This report is an example of how local hazard and risk information can be used to support mitigation efforts.

The scenario earthquake generates a local tsunami that arrives minutes after the earthquake mainshock. The maps depict potential structure and infrastructure damage and show locations likely to be flooded by a tsunami caused by a potential great earthquake (magnitude 8.4) occurring offshore on the Gorda segment of the Cascadia Subduction Zone.

The planning scenario includes damage probability and assessments for a variety of facilities, infrastructure, and services including: schools and colleges, hospitals, highways, airports, marine facilities, railroads, and facilities for electric power, natural gas, petroleum products, water supply, and wastewater. These assessments are intended to assist localities in planning for emergency response efforts and pre-disaster retrofitting and other risk mitigation efforts.



Excerpt from Scenario Map for Humboldt and Del Norte Counties.

Collateral Hazards and Compound Disasters

When considering the impacts of natural hazards on existing and future development, it is important to understand that, depending on the triggering event, many other problems may result. For example, earthquakes that generate local tsunamis also cause damage from strong shaking and secondary hazards such as ground failures from liquefaction and landsliding in the nearby coastal areas. Therefore, in developing mitigation programs it is important that all relevant hazards be considered, including the potential for their interactions to have combined effects on the area.

Insofar as tsunamis are concerned, onshore groundshaking and ground failures accompanying earthquake-generated local tsunamis may increase community vulnerability to the damage run-up area and make evacuation difficult. While perhaps unlikely coincidences, storm surges or outflows from rivers and streams during the rainy season could, depending on local circumstances, also increase inundation of higher elevation areas and the extent of tsunami damage due to higher water levels.

Also of concern are secondary emergencies that could be created by the initial disaster event, such as fires or spills at facilities that store or use hazardous materials. While not all variables can be controlled through mitigation programs, it is important to consider how various hazard-specific mitigation measures might be combined to help avoid compound disasters, such as properly bracing an elevated home that sits in a tsunami flood zone and is also subject to strong earthquake ground motion.

For local tsunamis, like Cascadia Subduction Zone events, liquefaction (the loss of strength and the settling or spreading of wet soft soil areas) and slope failures triggered by the earthquake are real possibilities. The combination of earthquake shaking and tsunami inundation and withdrawal may result in the loss of electricity, communications, potable water, wastewater, and natural gas services. Damage to local transportation systems, such as roadways, causeways, and bridge approaches, further adds to response problems by isolating barrier islands and peninsulas, and by making evacuation and search and rescue operations more difficult. In addition to tsunami-borne projectiles such as boats, shipping containers, logs, floating automobiles, and other materials, debris from earthquake-damaged buildings and coastal structures can increase damages.

Fires caused by ruptured fuel tanks and gas lines can be spread quickly by the tsunami inundation, as can spilled toxic materials. A unique characteristic of tsunami damage is the churning up and spreading of industrial and domestic wastes deposited for generations on the seafloor. While the highly regulated earthquake-resistant design of nuclear power plants far exceeds that required of new buildings, nuclear power plants located on the coast must be designed to prevent tsunami damage.

THINKING ABOUT MANAGING THE RISK TO YOUR COMMUNITY

Mitigating the risk from natural hazards can draw on a wide range of activities that have one overriding goal: to lessen future losses from natural hazard events. The Federal Emergency Management Agency (FEMA) defines “hazard mitigation” as “sustained action taken to reduce

or eliminate long-term risk to people and property from hazards and their effects. In the context of coastal…construction, mitigation usually takes the form of siting, design, construction of the building…and (sometimes) the form of protective works…" (FEMA, 1999, 4-4)

As with other natural hazards, it is important to distinguish between the terms used in this field. Hazard is generally defined as the existence of a possible source of danger, such as a tsunami, that is capable of occurring at various places and times. FEMA, in the same 1999 publication, offers the following definitions:

> **Hazard Identification** means the process of defining and describing a hazard (including its physical characteristics, magnitude, severity, frequency, and causative factors) and the locations or areas it affects.
>
> **Risk** means the potential losses associated with a hazard, defined in terms of expected probability and frequency, exposure, and consequences.
>
> **Risk Assessment** means a process or method for evaluating risk that is associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude and severity, exposure, and consequences.
>
> **Risk Management** means measures taken to reduce, modify, offset, or share risks associated with development in areas subject to…hazards. (FEMA, 1999, 4-4)

While the concept of mitigation is simple, there are many complex issues involved in achieving effective mitigation. Mitigation actions involve public policy, intergovernmental relations, public-private partnerships, economics, acceptable risk, and a wide range of specialized activities and programs. In all cases, mitigation programs and procedures are based on understanding the nature and probable severity of the hazard and the vulnerability of the area. Vulnerability assessments describe the weaknesses of buildings, systems and communities that make them susceptible to damage from the hazards.

Not all areas share the same hazard, vulnerability, and exposure. In general, a greater hazard justifies more rigorous mitigation measures. The key question becomes "How severe a problem are we dealing with in each community?" The answers to this question provide the basis for making public safety policy choices.

As with many natural hazards, exact probabilities or return intervals are extremely difficult to define, but two comparisons are instructive. First, California's building designs have been based on earthquakes expected to occur once every 475 years with the intent that collapse will not occur. In the Midwest, designs are based on avoiding collapse in earthquakes occurring once in 2,500 years. Second, flood loss prevention policies deal with events expected to occur every 100 to 500 years. While Hilo, Hawaii, has experienced numerous tsunamis, and Crescent City, California, experienced two damaging tsunamis in four years (1960 and 1964), many communities at risk have little or no recent history with tsunami damage.

Where development has not yet occured, one mitigation action is to avoid the hazard. This takes a combination of knowledge and a willingness by decisionmakers to set aside such areas and define them as unacceptable risks. Where development already exists or is virtually certain to occur, two fundamental strategies are available to help ensure that the potential effects of natural hazards are considered during the planning process. Although oversimplified, these two approaches are: 1) managing the hazard; and 2) managing the development. For example, managing the hazard by improving drainage can help control small-scale flooding and keep developed areas dry. Managing the development, for example, by avoiding constructing improvements in high-velocity floodplains and landslide-prone hillsides may be more effective and less environmentally disruptive than building expensive structures to control flooding or landslides.

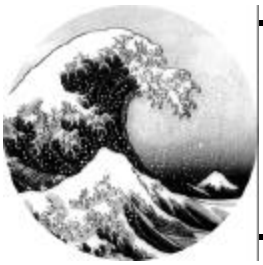
Although probabilities of occurrence may be extremely difficult to establish for tsunamis, using an approach similar to the application of probabilities to other hazards may be helpful. For example, a possible approach for tsunami mitigation is to prevent development or limit it to coastal-dependent facilities designed to the expected tsunami forces where tsunamis are expected once in every 100 years. Near-shore rapid-onset events (locally-generated tsunamis) could be subject to similar controls where tsunamis are expected once in every 500 years. In areas likely to experience tsunamis once in every 2,500 years, at least adequate evacuation precautions should exist, such as designing for vertical evacuation, designating "safe buildings," and maintaining effective plans for horizontal evacuation from low-lying to higher ground areas. This is especially true for areas with large resident or visitor coastal populations "at risk," such as beach communities.

Land use and mitigation actions taken for other reasons may also help limit tsunami damage. For example, preventing construction in floodplains, because of their highly saturated soils and low elevations, could reduce losses from tsunami inundation and earthquake groundshaking. Low density uses, such as parkways or protected habitat areas, could also help mitigate tsunami losses. For example, Hilo, Hawaii, and Crescent City, California, have large parks adjacent to their coastal areas. In Hilo, the park helped to significantly prevent greater losses from the March 28, 1964, tsunami generated by the Alaska Earthquake. Crescent City's park was created after the 1964 tsunami (although it existed as a broad beach previously). Buildings can be located, designed, and built to withstand tsunami inundation and serve as "vertical" evacuation centers. All of these subjects are discussed in other background papers.

APPENDIX 1-1:
SUGGESTED CONTENTS OF A TSUNAMI HAZARD STUDY

Objective: To define tsunami intensity and frequency in terms useful to comprehensive planning, regulatory, and design decisions. This information should establish the importance and describe the consequences of the hazard, and be useful for evaluating mitigating options and analyzing vulnerability of building and other facilities. It needs to provide a sound basis for planning and regulatory findings and for design criteria for structures located in the hazard zone. The information would be used for evacuation by defining likely time to evacuate and designations, and, if vertical evacuation is necessary, to evaluate the vulnerability of shelter buildings.

1. Description of potential sources and historical records affecting the site;
2. Description of the potential for subsidence and uplift of the area;
3. Elevation of wave at the beach above mean sea level (+/- 1 sigma range). The height of the breaking wave;
4. Drawdown elevation (give a +/- 1 sigma range);
5. Inundation depth (< 3 feet, 3 to 10 feet, > 10 feet) and limits of run-up at various points;
6. Current velocity for run-up and drawdown and bore potential at various locations;
7. Areas of expected erosion (e.g., current velocity > x feet per second and location of wave break);
8. Debris load estimates for typical pre-tsunami conditions and during an event:
   None—Debris unlikely, inundation < 3 feet, low velocity currents;
   Low—Little potential for debris, low velocity currents and inundation depth < 3 feet;
   Moderate —Moderate potential for amount and size of debris, moderate velocity currents and inundation depth (3 to 10 feet);
   Severe—High potential for a large amount and size of debris, high velocity currents, inundation depth >10 feet;
9. Potential for entrained and tossed stones in the wave break;
10. Time between event initiation and arrival at the site;
11. Number of waves or time span of event;
12. Probability of occurrence:
    Occasional—50 percent chance of exceedance in 50 years (1/72 years);
    Rare—10 percent chance of exceedance in 50 years (1/475 years);
    Very Rare—2 percent chance of exceedance in 50 years (1/2,500 years);
    Maximum Considered Event—Worst case possible under consideration (1/2,500-5,000 years);
13. Level of certainty:
    Low—Based on the opinion of a tsunami specialist after a site reconnaissance, review of published hydrographic and topographic maps, and review of written and paleoseismological history;
    Moderate—Based on the above factors plus modeling of waves from a variety of source zones;
    High—Based on the above plus probability of events calculated by combining individual events and run-up and drawdown model.



BACKGROUND PAPER #2: LOCAL, STATE, AND FEDERAL FRAMEWORK FOR LAND USE PLANNING AND COASTAL DEVELOPMENT

INTRODUCTION

This background paper describes the local, state, and federal framework for land use planning and coastal development in the five Pacific states. For each state the paper summarizes the basic legal structure of state and local planning, with particular regard to seismic safety and tsunami hazards.

The paper starts with a summary of federal policies and requirements, including the Coastal Zone Management Program, the Coastal Zone Enhancement Program, and the National Flood Insurance Program (NFIP). The paper then discusses land use planning requirements for the five Pacific states, including state requirements for local comprehensive plans, local development regulations, and local zoning ordinances; state requirements for local building codes; and state coastal management policies.

KEY CONCEPTS AND FINDINGS

The following is a summary of the land use planning and development regulations in the five Pacific states:

- All five Pacific states require local land use planning, and all except Alaska have statewide planning guidelines. Alaska has statewide planning guidelines for coastal resource districts.

- Oregon and Washington require local plans to be consistent with statewide planning goals. California and Hawaii have statewide planning guidelines that are advisory only. Alaska requires a consistency review of coastal resource district plans with statewide standards and with other districts' plans.

- California, Oregon, and Washington require hazard mitigation as part of their general land use planning process. Alaska requires it for coastal resource district plans only. Hawaii only suggests that this topic be addressed.

- Three of five Pacific states require conformance with a state model building code based on the Uniform Building Code (UBC). Alaska only mandates adoption of a fire code and Hawaii does not have a state-mandated building code. All of the counties in Hawaii and the larger cities in Alaska have adopted a version of the UBC. Codes and standards are discussed in more depth in Background Paper #5, *Building Design*.

OVERVIEW OF FEDERAL POLICIES AND REQUIREMENTS

While the federal government has supported state and local planning through numerous programs over the years, there are no federal requirements for statewide or local land use planning. There are, however, federal programs that have implications for land use planning in coastal areas.

In 1972, Congress passed the Coastal Zone Management Act (CZMA) to promote the orderly development and protection of the country's coastal resources. The CZMA established a voluntary partnership among the federal government, coastal states, and local governments to develop individual state programs for managing coastal resources.

The national system for the management of the nation's coastal and ocean resources, put into place by the CZMA, has federal and state components. The federal component is located within the Office of Ocean and Coastal Resource Management (OCRM), which is part of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). The state component consists of federally-approved coastal management programs (CMPs) in 32 coastal states and territories. The National Coastal Zone Management (CZM) Program is authorized by the CZMA to:

- Preserve, protect, develop, and where possible, restore and enhance the resources of the coastal zone;

- Encourage and assist the states to exercise effectively their responsibilities in the coastal zone to achieve appropriate use of land and water resources of the coastal zone, giving full consideration to ecological, cultural, historic, and aesthetic values as well as the need for compatible economic development;

- Encourage the preparation of special area management plans to provide increased specificity in protecting significant natural resources, reasonable coastal-dependent economic growth, improved protection of life and property in hazardous areas, and improved predictability in governmental decisionmaking; and

- Encourage the participation, cooperation, and coordination of the public, federal, state, local, interstate and regional agencies, and governments affecting the coastal zone.

Since 1974, with the approval of the first state Coastal Management Program (CMP) in the state of Washington, a total of 28 coastal states and five island territories have developed CMPs. Together these programs protect more than 99 percent of the nation's 95,439 miles of oceanic and Great Lakes coastline. CMPs are expected to consider or undertake the following:

- Protection of natural resources;
- Manage development in high hazard areas;
- Manage development to achieve quality coastal waters;
- Give development priority to coastal-dependent uses;
- Have orderly processes for the siting of major facilities;

- Locate new commercial and industrial development in or adjacent to existing developed areas;
- Provide public access for recreation;
- Redevelop urban waterfronts and ports, and preserve and restore historic, cultural, and aesthetic coastal features;
- Simplify and expedite governmental decisionmaking actions;
- Coordinate state and federal actions;
- Give adequate consideration to the views of federal agencies;
- Assure that the public and local government has a say in coastal decisionmaking; and
- Comprehensively plan for and manage living marine resources.

In 1990, to meet mounting public concern for the well-being of the nation's coastal resources, the Congress created the Coastal Zone Enhancement Program, a new program under the Coastal Zone Management Act. The Coastal Zone Enhancement Program provides incentives for states and territories to make changes in any of eight areas of national significance. They are:

- Wetlands protection;
- Coastal hazards;
- Cumulative and secondary impacts of development;
- Public access to the coast;
- Special area management planning;
- Ocean governance;
- Marine debris; and
- Government and energy facility siting.

The National Flood Insurance Program (NFIP) established in 1968 and amended by the Flood Disaster Protection Act of 1973 and Title V (National Flood Insurance Reform Act) of the Reigle Community Development and Regulatory Improvement Act of 1994, is part of a comprehensive approach to reduce flood damage and to cope with the disastrous effect of floods. The NFIP is administered by the Federal Insurance Administration (FIA), a component of the Federal Emergency Management Agency (FEMA). The NFIP makes federally-backed flood insurance available in communities that adopt and enforce floodplain management ordinances to reduce future flood losses.

The NFIP consists of two essential components:

1) Management guidelines for new development and major changes to existing development in Special Flood Hazard Area (SFHAs); and
2) Insurance to cover the risks of existing construction.

The Special Flood Hazard Area (SFHA) is the land in the floodplain that has a one percent or greater chance of flooding in any given year. The purpose of the management component is to minimize the potential for flood damage by controlling reconstruction and/or development in SFHAs. To accomplish this, communities are required to adopt and administer regulations for the efficient and effective use of SFHAs and for the control, location, and design of structures in order to minimize damage by flooding. The community can protect residents against disasters and avoid and/or minimize the disruption of public services. Communities are encouraged to plan and achieve a development pattern that:

- Avoids damage-prone uses in floodplains;
- Reduces development pressure in flood hazard areas; and
- Encourages compatible uses.

The role of the FIA in hazard mitigation is to identify the 100-year hazard areas, including the elevation of flooding above sea level and ensure that the regulations of participating communities comply with the NFIP floodplain management requirements. The NFIP defines specific regulatory standards that local communities are required to meet to participate in the program. This "standards" approach is much more specific than the "goals" approach of the CZM Program and requires, for example, that communities regulate structural design standards. FIA studies conducted in the 1970s identified only the threat from distant tsunamis.

Floodplain management means a comprehensive community program of corrective and preventive measures for reducing future flood damage. These measures may take a number of forms, but typically include improved building codes and subdivision regulations, as well as zoning, drainage provisions, and other special-purpose floodplain ordinances. The cumulative effect of these measures and ordinances is the construction of new structures that are better protected from the affects of flooding, whether it be tidal or inland.

There are several SFHA zones that apply specifically to coastal areas:

- Zone V: SFHAs along coasts subject to inundation by the 100-year flood with the additional hazards associated with storm waves. Because detailed hydraulic analyses have not been performed, no base flood elevations or depths are shown. Mandatory flood insurance purchase requirements apply.

- Zones VE and V1-30: SFHAs along coasts subject to inundation by the 100-year flood with additional hazards due to velocity (wave action). Base flood elevations derived from detailed hydraulic analyses are shown within these zones. Mandatory flood insurance purchase requirements apply. (Zone VE is used on new and revised maps in place of Zones V1-30.)

FEMA's V Zone mapping does not examine tsunami hazards and only accounts for tsunamis coincidentally where coastal flood areas overlap tsunami hazard areas.

Wave generated by the 1946 tsunami in the Keaukaha area of Hilo, Hawaii.
Credit: Pacific Tsunami Museum

STATE POLICIES, REQUIREMENTS, AND PROGRAMS

All five Pacific states require local land use planning, and all except Alaska have statewide planning guidelines (Alaska has statewide planning guidelines for coastal resource districts only).

Building construction in the United States is governed at the local level by building codes. Building codes establish minimum acceptable requirements for protecting life, addressing property damage, and preserving the public health, safety, and welfare in the built environment. The local building codes used in the states bordering the Pacific Ocean are modified or unmodified versions of the Uniform Building Code (UBC) prepared by the International Conference of Building Officials. Three of the five Pacific states require adoption and enforcement of the statewide building code at the local level.

The following is an overview of the land use planning, building code, and coastal management policies of the five Pacific states: Alaska, California, Hawaii, Oregon, and Washington.

Alaska

Local Comprehensive Plan

Title 29 of Alaska Statutes (Municipal Government) requires all first or second class boroughs in Alaska to "provide for planning, platting, and land use regulation on an areawide basis" (Sec. 29.40.010). Areas of the state that are not within the boundaries of an organized borough constitute a single unorganized borough. The Department of Natural Resources is the platting authority for the state except within a municipality that has the power of land use regulation and that is exercising its platting authority.

Each first and second class borough is also required to establish a planning commission by ordinance. The planning commission is required by state law to prepare and submit to the borough assembly a proposed comprehensive plan for the systematic and organized development

of the borough. The commissions also review, recommend, and administer measures necessary to implement the comprehensive plan.

The comprehensive plan "is a compilation of policy statements, goals, standards, and maps for guiding the physical, social, and economic development, both private and public, of the first or second class borough, and may include, but is not limited to, the following:

- Statements of policies, goals, and standards;
- A land use plan;
- A community facilities plan;
- A transportation plan; and
- Recommendations for implementation of the comprehensive plan." (Sec. 29.40.030).

The State of Alaska specifies the elements of land use plans for coastal resource (coastal plans), and requires a hazard mitigation element for these plans.

Local Development Regulations/Programs

Alaskan communities must have an adopted comprehensive plan before they may adopt land use regulations such as a zoning ordinance. Section 29.40.040 states that, in order to implement a comprehensive plan, "the assembly by ordinance shall adopt or amend provisions governing the use and occupancy of land that may include, but are not limited to:

- Zoning regulations restricting the use of land and improvements by geographic districts;
- Land use permit requirements designed to encourage or discourage specified uses and construction of specified structures, or to minimize unfavorable effects of uses and the construction of structures; and
- Measures to further the goals and objectives of the comprehensive plan."

The Alaska State Code, based on the fire code provisions of the 1997 Uniform Building Code (UBC), applies to all types of structures in the state, except for residential structures. State law allows for some modifications at the city/county level based on unique local conditions. All of the larger cities in Alaska have adopted a version of the UBC.

State Coastal Policies

The Alaska Coastal Management Program (ACMP) implements the Alaska Coastal Management Act passed by the State of Alaska in 1977. The ACMP was designed to respond to the federal Coastal Zone Management Act (CZMA). The Alaska Division of Governmental Coordination (DGC) in the Office of the Governor is the lead agency responsible for the overall administration and operation of the ACMP.

The ACMP is intended to improve stewardship of Alaska's coastal land and water uses, and natural resources, by creating a network of local, state, federal, and applicant interests in the project approval process. While the program is coordinated at the state level, coastal districts develop locally-specific program standards that are incorporated into the state program and used

for project reviews. The Coastal Policy Council, which provides general program oversight, brings together representatives from 17 state agencies and includes nine members representing local governments.

The ACMP requires that projects in Alaska's coastal zone be reviewed by coastal resource management professionals and found consistent with the statewide standards of the ACMP in a "consistency review process."

The ACMP applies to projects within or affecting Alaska's coastal zone. Alaska's coastal zone boundaries include the coastline proper and can extend inland along river drainages as far as 250 miles. The statewide standards (6 AAC 80) and coastal district enforceable policies of the ACMP provide direction for coastal resources and uses, such as:

- Coastal development (whether a project is water-dependent or water-related);
- Habitats (such as wetlands, tideflats, or streams);
- Air, land, and water quality;
- Transportation and utility routes and facilities;
- Timber harvest;
- Mining and mineral processing;
- Subsistence opportunities;
- Recreation designations;
- Geophysical hazard areas (defined as "those areas which present a threat to life or property from geophysical or geological hazards, including flooding, tsunami run-up, storm surge run-up, landslides, snowslides, faults, ice hazards, erosion, and littoral beach process" (6 AAC 80.900(a)(9));
- Historical and archaeological resources;
- Energy facilities; and
- Fish and seafood processing.

Using the statewide standards and local enforceable policies, the ACMP evaluates the effects a project will have on the above coastal resources and uses. A finding of consistency with the ACMP must be obtained before permits can be issued for the project.

Coastal districts are generally local governments, such as cities and boroughs, that contain a portion of Alaska's coastal area. In coastal areas outside the boundaries of local government, coastal districts known as Coastal Resource Service Areas (CRSA) may be formed. Most coastal districts develop a coastal management program that requires a rigorous state and federal approval process. A district coastal management program contains enforceable policies that guide development affecting the coastal resources within its boundaries. Once approved, a district coastal management program becomes a part of the ACMP.

State Role

While state law in Alaska requires preparation of general plans and specifies the basic content of the general plan, there are no statewide goals that general plans are required to meet.

The Coastal Management Programs of Coastal Districts are required to be reviewed and approved by the state before they become a part of the Alaska Coastal Management Program (ACMP).

The Alaska Constitution specifically provides for local self government. However, the Constitution also recognizes that many local governments in the state were not fully developed and would not have the resources to achieve strong local self-determination unless they were assisted in this effort. A large part of the state consists of the "unorganized borough" in which there is no regional form of government. The Municipal and Regional Assistance Division (MRAD) of the Department of Community and Economic Development (DCED) fulfills the mandated assistance function by offering local governments and other community entities a broad range of support for local development efforts.

MRAD's Community Planning Program provides assistance to communities on regional and community planning issues. The main areas of assistance include: Alaska Coastal Management Program implementation through local districts; National Flood Insurance Program (NFIP) administration and planning; and technical advice and training on general community and regional planning efforts.

California

Local Comprehensive Plan

In California, comprehensive plans are known as "general plans." By state law, every city and county must adopt its own general plan for long-term physical development (Government Code Section 65300 et seq.). The plan serves as the basis for all land use decisions within the jurisdiction. It is required to be comprehensive, internally consistent, and long term.

The plan is required to cover a jurisdiction's entire planning area and address the broad range of issues associated with a city's or county's development. State law requires that each general plan address at a minimum a comprehensive list of development issues falling under seven major categories or "elements": land use, circulation, housing, conservation, open space, noise, and safety.

The goal of the safety element is to reduce the potential risk of death, injuries, property damage, and the economic and social dislocation resulting from hazards such as fires, floods, earthquakes, landslides, and other hazards such as tsunamis. The safety element's identification of hazards and hazard abatement provisions are intended to guide local decisions related to zoning, subdivisions, and entitlement permits. Policies in this element are supposed to address the identification of hazards and implications for emergency response, as well as mitigation through avoidance of hazards by new projects and reduction of risk in developed areas.

Prior to preparing or revising its safety element, a city or county must consult with the Office of Emergency Services and submit one copy of its draft safety element to the Division of Mines and Geology for review (Government Code Section 65302(g)).

Local Development Regulations/Programs

State law authorizes implementation of the local general plans through zoning, subdivision procedures, preparation of specific plans, capital facility programming, redevelopment, and development agreements. Based on statutory and case law, the use of all these implementation tools must be consistent with the local general plan.

State law requires that all cities and counties adopt building codes that are consistent with state-adopted model codes (as of July 1, 1999, based on the 1997 Uniform Building Code (UBC)). State law provides for State modification of the model codes and allows for some variations at the city/county level based on unique local conditions.

State Coastal Policies

The California Coastal Management Program (CCMP) was designed to respond to the federal Coastal Zone Management Act (CZMA) and was certified by the federal government in 1978. The enforceable policies of that document are contained in Chapter 3 of the California Coastal Act of 1976 (Public Resources Code Section 30000 et seq.). The California Coastal Commission is the lead agency responsible for the overall administration and operation of the CCMP.

Coastal cities and counties are subject to both the Planning and Zoning Law (as described above) and the California Coastal Act. The California Coastal Act applies to the coastal zone, a strip along the California coast generally "extending seaward to the state's outer limit of jurisdiction, including all offshore islands, and extending inland generally 1,000 yards from the mean high tide line of the sea." (Public Resources Code Section 30103)

Each city or county lying wholly or partly within the coastal zone must prepare a Local Coastal Plan (LCP) for that part of its jurisdiction within the zone or request that the Coastal Commission prepare an LCP for them. An LCP consists of a coastal land use plan (i.e., portions of a city's or county's general plan), zoning ordinance, zoning district maps, and where required, other programs necessary to implement the Coastal Act. In addition, it must contain a specific public access component to assure that maximum public access to the coast and public recreation areas is provided.

While the Coastal Act provides that the content of each LCP is to be determined by the local government in full consultation with the Commission and with full public participation, the LCP must address a list of policies that can be grouped under the following seven headings: access, recreational and visitor-serving uses, marine resources, agriculture, new development, public works, and coastal-dependent industrial development. The contents of coastal land use plans overlap most of the required content of general plans, and, for this reason, many local governments have integrated their coastal land use plans in their general plans. The specific contents of local coastal plans (LCPs) are not specified by state law. However, LCPs must be certified by the Coastal Commission as consistent with policies of the Coastal Act. It should be noted that since tsunami hazard areas can and do exceed the boundaries of the Coastal Zone, LCP policies cannot be relied upon exclusively to mitigate the tsunami risk.

The Coastal Act (Public Resources Code, Division 20) has provisions relating to geologic hazards, but does not mention tsunamis specifically. Section 30253(1) states that "new development shall minimize risks to life and property in areas of high geologic, flood, and fire hazard." Section 30610.1(c)(3) states that coastal development permits shall be required for the construction of single-family residences on vacant lots that are "located within an area known to the affected local government, or designated by any other public agency, as a geologic hazard area or as a flood hazard area...", unless it has been "determined by the affected local government to be a safe site for the construction of a single-family residence."

The 1965 McAteer-Petris Act established the San Francisco Bay Conservation and Development Commission (BCDC) as a state agency. The San Francisco Bay Plan, completed in 1969 and subsequently incorporated into state law, includes policies on 18 issues critical to the use of the Bay ranging from ports and public access to design considerations and weather. The 1969 revisions to the Act further specified that the San Francisco Bay Conservation and Development Commission is the permanent agency responsible for maintaining the Bay Plan and carrying out the provisions of the law. Over the years, the Commission has adopted a number of amendments to the Bay Plan, and the Legislature has amended the McAteer-Petris Act several times.

State Role

While State law requires the preparation of general plans and specifies the basic content of the general plan (including the required elements), there is no state land use plan or set of statewide goals or policies that general plans are required to meet. The Governor's Office of Planning and Research publishes the *General Plan Guidelines*, but these are advisory only.

The specific contents of Local Coastal Plans (LCPs) are not specified by state law either. However, LCPs must be certified by the Coastal Commission as consistent policies of the Coastal Act. In practice, the Coastal Commission has been very aggressive in ensuring conformance with Coastal Act policies.

The Seismic Hazards Mapping Act directs the State Geologist to compile maps identifying seismic hazards for use by local governments. The Act does not require the State Geologist to prepare maps for tsunamis or seiche hazards unless there is supplemental funding. The State Geologist, however, can adopt tsunami and seiche hazard maps prepared by other agencies. The State hazards maps are to be used in preparing local general plans and trigger requirements for geotechnical reports in connection with local government review and approval of individual project proposals.

Hawaii

Local Comprehensive Plan

Hawaii's Land Use Law, passed in 1961, provides for the regulation of land use and development throughout the state. The Land Use Commission establishes boundaries for districting of all lands and serves as a quasi-judicial body in administering the land use law. The Land Use Law established four State Land Use Districts that are applied to all land in the state:

urban, agricultural, conservation, and rural. State law defines the standards for determining the boundaries of these districts and the permissible uses in these districts.

The State Planning Act (Hawaii Revised Statutes, Chapter 226), passed in 1978, was designed to improve the statewide planning process, improve coordination among different agencies and levels of government, and provide guidelines for future development. It provides overall goals, objectives, and policies to serve as guidelines for decisionmaking about future long-range development at the state and local level. The Hawaii State Plan is the long-range comprehensive plan. It includes the overall theme, goals, objectives, policies, priority guidelines, and implementation mechanisms established under the State Planning Act.

The Hawaii State Plan's section on air and water quality objectives and policies includes the following policy: "Reduce the threat to life and property from erosion, flooding, tsunamis, hurricanes, earthquakes, volcanic eruptions, and other natural or man-induced hazards and disasters." The State of Hawaii suggests, but does not require, that a hazard mitigation element be included in the required local comprehensive plans.

Local Development Regulations/Programs

Hawaii Revised Statutes (HRS) 46-4 mandate that zoning in all counties shall be accomplished within the framework of a long-range comprehensive general plan. Zoning is one of the primary tools available to the county governments to put the general plan into effect.

Hawaii does not have a state-mandated building code. However, all four county governments in Hawaii have adopted the 1991 Uniform Building Code (UBC), and are considering adopting the 1997 edition.

State Coastal Policies

The Hawaii Coastal Zone Management (CZM) Program (Chapter 205A, HRS) was promulgated in 1977 in response to the federal Coastal Zone Management Act (CZMA). The program includes the following policy areas: historical resources; recreational resources; scenic and open space resources; coastal ecosystems; economic uses; coastal hazards (including tsunamis); managing development; public participation; beach protection; and marine resources. The Department of Business, Economic Development, and Tourism is the lead agency responsible for the overall administration and operation of the Hawaii CZM Program.

Other key areas of the CZM Program include: a permit system to control development within a Special Management Area (SMA) managed by the counties and the Office of Planning, and a Shoreline Setback Area which serves as a buffer against coastal hazards and erosion, and protects viewsheds. A major objective of the CZM Program is to reduce hazard to life and property from tsunamis, storm waves, stream flooding, erosion, and subsidence.

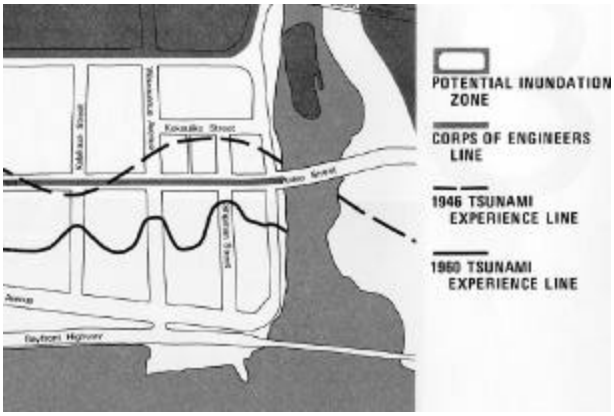
The Special Management Area (SMA) and Shoreline Setback Area are designated for more intensive management by the four counties. The SMA originally encompassed all lands extending not less than 100 yards inland from the shoreline. In some areas, the SMAs extend

several miles inland to cover areas in which coastal resources are likely to be directly affected by development activities, such as Kawainui Marsh on Oahu and Waipio Valley on Hawaii. Counties may amend their boundaries to achieve the CZM objectives and policies. Amendments removing areas from an SMA are subject to state review for compliance with the coastal law.

No development can occur in the SMA unless the appropriate county (or for developments in the Community Development Districts, the Office of Planning) first issues a permit. Development is defined to include most uses, activities, and operations on land and in the water.

Since 1992, the CZM Program has commissioned a number of studies in support of hazard mitigation. The CZM Program supported two phases of a coastal hazard mapping project. These studies resulted in the Atlas of Natural Hazards in the Hawaiian Coastal Zone. The Atlas identifies and ranks the severity of a range of coastal hazards for the coastline of the main Hawaiian Islands, including tsunami, stream flooding, high waves, storms, erosion, sea level rise, and volcanic and seismic hazards. The Atlas does not define the inland boundary of the hazards. However, it is intended as a tool for planners, developers, and regulators in determining if a particular hazard needs to be assessed in planning development and reviewing permit applications for a specific shoreline area.

There have been other recent efforts in local hazard mitigation planning. The Coastal Hazard Mitigation Planning Project (CHMPP) began with support from the CZM Program. Phase I analyzed the hurricane risk in Hawaii and the costs and benefits of a range of hazard mitigation activities. It resulted in recommendations to the state to reduce the risk of hurricane damage in Hawaii including: adoption of the 1991 UBC by county governments; improving enforcement of shoreline setback regulations; evaluating the feasibility of variable (risk-based) shoreline setbacks; designating high hazard areas on planning and zoning maps; conducting risk audits and retrofits for public buildings; and providing incentives for retrofitting homes through tax incentives and risk-based hurricane insurance premiums. The 1994 Legislature adopted the majority of these recommendations by joint resolution. Since then, many recommendations have been implemented by state and county agencies.



An excerpt from the tsunami inundation map in the *Hilo Downtown Development Plan*.
Credit: County of Hawaii

Phase II of the CHMPP began in 1994. The project team worked with the county governments to evaluate the feasibility of designating high hazard areas in four specific geographic areas. The project team also developed a hazard mitigation plan for high hazard areas, including a risk-based premium rate structure with financial support from the Federal Emergency Management Agency (FEMA) with credits for mitigation. In addition, a brochure on hurricane awareness describing measures that homeowners can follow to reduce the risk of hurricane damage was prepared and distributed through county building departments.

State Role

The establishment of the location of and permissible uses in State Land Use Districts leaves county governments with a reduced role in land use planning. However, while county general plans or development plans are required to "further define the overall theme, goals, objectives, policies, and priority guidelines" of the State Planning Act, the specific content of these plans is not defined. While the formulation, amendment, and implementation of county general plans or development plans are required to include input from the state and county agencies as well as the general public, and to take into consideration statewide objectives, policies, and programs stipulated in state functional plans (including the Hawaii State Plan), there is no formal review or approval of county general plans at the state level.

Despite the efforts to coordinate coastal hazards planning, the Coastal Hazard Mitigation Planning Project concluded in a recent study that hazard considerations are not a routine part of permit and other land use planning decisions. To address this gap, a hazard assessment-identifying areas subject to coastal erosion, lava flow, flood, tsunami damage, earthquake zones, storm surge damage, and strong winds-has been recommended to be integrated into the various levels of planning, land use decisionmaking, permitting, and land management in Hawaii. The hazard assessment will identify the specific hazard exposures for proposed uses at a site and the mitigation measures that will be employed to reduce the risk of losses.

Oregon

Local Comprehensive Plan

Oregon's State Land Use Act, passed in 1973, created Oregon's Land Use Program (Oregon Revised Statutes, Chapter 197). The foundation of the program is a set of 19 statewide planning goals. The goals express the state's policies on land use and related topics, such as citizen involvement, housing, and natural resources. Oregon's statewide planning program is directed by the Land Conservation and Development Commission (LCDC).

Oregon's statewide goals are achieved through local comprehensive planning. State law requires each city and county to have a comprehensive plan and the zoning and land-division ordinances needed to put the plan into effect. The local comprehensive plans are required to be consistent with the statewide planning goals. Plans are reviewed for consistency by LCDC. When LCDC officially approves a local government's plan, the plan is said to be "acknowledged." It then becomes the controlling document for land use in the area covered by that plan. Oregon's planning laws apply not only to local governments but also to special districts and state agencies.

The laws strongly emphasize coordination-keeping plans and programs consistent with each other, with the goals, and with acknowledged local plans.

A comprehensive plan is an official document adopted by a city or county that sets forth the general, long-range policies on how the community's future development should occur. The local comprehensive plan guides a community's land use, conservation of natural resources, economic development, and public services. Plans must address all the applicable topics in the statewide planning goals, as well as issues of local concern. Plans must anticipate and provide for future land use needs. Comprehensive plans must include special plan elements for coastal resources including estuaries, shorelands, beaches, and dunes.

The State of Oregon requires that hazard mitigation be addressed in the required local comprehensive plans (under Goal 7: Areas Subject to Natural Disasters and Hazards). It requires that jurisdictions apply "appropriate safeguards" (floodplain zoning, for example) when planning for development in these areas.

As of September 2000, LCDC was considering amendments to Statewide Planning Goal 7. The Governor directed LCDC to review the effectiveness of Goal 7 in reducing risks from natural hazards after flood and landslide events in 1996 and 1997. The revised language refers directly to tsunami hazards. Also, in response to these issues, the Department of Land Conservation and Development (DLCD) released a new hazards planning guide in August, 2000, entitled *Planning for Natural Hazards: Oregon Technical Resource Guide.*

Local Development Regulations/Programs

State law requires adoption of implementing measures to carry out the comprehensive plan. The two most common measures are zoning and land division ordinances. Every city and county in Oregon has adopted such land use controls. All land use ordinances must be consistent with and carry out the comprehensive plan.

The Oregon Structural Specialty code, based on the 1997 Uniform Building Code (UBC), applies to non-residential and multi-family residential structures. The One and Two Family Dwelling Code applies to other residential properties. State law allows for some variations at the city/county level based on unique local conditions.

State Coastal Policies

Oregon's Coastal Management Program (OCMP) was approved in 1977 as a response to the federal Coastal Zone Management Act (CZMA). The objective of the OCMP is to develop, implement, and continuously improve a management program which will, as appropriate, preserve, conserve, develop, and restore the natural resources of the coastal zone. The Department of Land Conservation and Development (DLCD) is the lead agency responsible for the overall administration and operation of the OCMP.

The Oregon Coastal Management Program (OCMP) is part of Oregon's statewide program for coordinated land use planning. Relying on a partnership between the public, local governments,

and state and federal agencies, the OCMP is based on three separate but coordinated sets of planning and regulatory authorities: 1) statewide planning goals adopted by the LCDC; 2) acknowledged comprehensive plans which local governments have developed and LCDC has approved; and 3) specified statutory authorities of various state agencies (these include the Removal-Fill Law), which regulates alterations to estuaries, lakes, and other waterways, and the Oregon Beach Bill which regulates uses and alterations along the ocean shore. Supplementing these laws are authorities and capabilities derived from the federal Coastal Zone Management Act.

Together, these authorities establish policies and procedures for planning and managing the balanced preservation, conservation, use, development, and restoration of the natural resources in Oregon's coastal zone. These authorities are tied together by two requirements in Oregon's Land Use Planning Act and the statewide planning goals. First, the Act requires all units of government to coordinate their actions affecting land use with affected citizens and with local, state, and federal agencies. Second, the Act requires that the plans and actions of all agencies and local governments comply with the statewide planning goals and acknowledged comprehensive plans.

Oregon’s Coastal Zone includes all the lands west of the crest of the Coast Range Mountains, except in the Rogue, Umpqua, and Columbia River basins. The Coastal Zone encompasses seven coastal counties, five inland counties, and 33 cities.

Each coastal comprehensive plan includes special development restrictions to recognize and protect special shorelands values. Coastal shorelands boundaries are a minimum of 50 feet inland for the shorelands and may be more when special circumstances apply, including coastal geologic hazard areas and areas subject to coastal flooding. More than a third of the land in the coastal zone is owned by the federal government.

In cooperation with interested stakeholders, the Department of Land Conservation and Development (DLCD) developed and has been carrying out a multi-year strategy to improve coastal hazards management in Oregon. Projects and activities in the three general areas of hazard policy, assessment, and education were identified and have been conducted or funded by the department during the last several years.

These projects and activities are designed to improve some aspect of natural hazards management on the coast. For over two years, the Hazards Policy Working Group met to examine natural hazards policy in Oregon. Through an innovative "all-hazards, all-decisions" approach, they evaluated the effectiveness of existing policy and policy implementation. The group identified 23 coastal hazards issues and 79 recommendations for improved policies and practices in the areas of hazard assessment, land use, shore protection and emergency response. The *Planning for Natural Hazards: Oregon Technical Resource Guide* report has been widely distributed, and implementation of many of those recommendations is currently underway. The document is intended to help local governments strengthen the natural hazards element of their comprehensive land use plans. The Guide provides information on how to identify, plan for, and implement programs to address floods, landslides, wildfire, seismic, and coastal hazards. It

provides information for communities to help implement both regulatory and nonregulatory programs to minimize the impact of natural hazards.

Existing policies do not address seismic hazards in any significant way. DLCD states that it needs to participate in the on-going debate and discussion on the risks of seismic hazards and ways to address them. The coast is particularly at risk from a Cascadia Subduction Zone event because of the proximity to the fault zone and the added tsunami hazard.

State Role

Most of the statewide planning goals are accompanied by guidelines, which are suggestions about how a goal may be applied. While the goals are mandatory and have been adopted as administrative rules (Oregon Administrative Rules Chapter 660, Division 15), the guidelines are not mandatory. In addition to the goals, LCDC has also adopted Administrative Rules to guide state and local planning.

Section 455.446 of the Oregon Revised Statutes (ORS) requires the State Department of Geology and Mineral Industries to define tsunami inundation zones (see Background Paper #6, Appendix 1). This ORS section also prohibits, with exceptions, new “essential facilities” and new “special occupancy structures” in tsunami inundation zones. Furthermore, the statutes provide that those new essential facilities, hazardous facilities and major structures, and new special occupancy structures that are allowed to locate in a tsunami inundation zone must consult with the State Department of Geology and Mineral Industries for assistance in determining the impact of possible tsunamis on the proposed development and for assistance in preparing methods to mitigate risk before a building permit is issued.

Washington

Local Comprehensive Plan

In 1990, Washington adopted the Growth Management Act (GMA) (Revised Code of Washington 36.70A.020). This law established a growth management program designed to reduce sprawl. Inspired by Oregon's program, the act has 13 statewide planning goals. In 1991, the Legislature established three regional Growth Management Hearing Boards located in Spokane, Olympia, and Seattle. The boards hear appeals brought by citizens and by the state to ensure that local plans are consistent with the statewide goals. The GMA requires the fastest-growing counties, and the cities within them, to adopt comprehensive plans. Twenty-nine counties and 215 cities, representing 95 percent of the state's population, are planning under the GMA.

County plans must harmonize with the plans of cities within the county, and the plans of neighboring jurisdictions must correspond with one another. Unlike Oregon, Washington opted for stronger local autonomy and does not require state approval of local plans. Jurisdictions that refuse to plan, or whose plans fail to address key issues, lose eligibility for state-infrastructure grants and loans. The governor may also withhold sales, liquor, and gas tax revenue.

Counties and cities required to complete a comprehensive plan are required to designate "critical areas," including geologically hazardous areas, and adopt regulations that preclude incompatible land uses or development in these areas.

Local Development Regulations/Programs

Within one year of adopting a plan, municipalities must enact zoning rules and capital improvement programs consistent with the plan. Local zoning decisions may be challenged in court if they contradict local planning policies.

The Washington State Building Code, based on the 1997 Uniform Building Code (UBC), applies to all types of structures in the state. State law allows for some modifications at the city/county level based on unique local conditions.

State Coastal Policies

The Washington Shoreline Management Act (SMA) requires that all shoreline uses and activities be consistent with the SMA and requirements of the local Shoreline Management Plan (SMP).

The Washington Shoreline Management Act (SMA) was designed to respond to the federal Coastal Zone Management Act (CZMA). All cities and counties with "shorelines of the state" are required to adopt shoreline master programs (SMPs). "Shorelines of the state" include all water areas of the state, excluding streams under 20 cfs and lakes less than 20 acres, together with their associated shorelands extending 200 feet from the water, their floodplains and associated wetlands, plus adjacent lands (Revised Code of Washington (RCW) 90.58.340). Shoreline Master Programs (SMPs) are both planning and regulatory (implementation) tools; they are analogous to comprehensive plan policies and development regulations respectively. The Department of Ecology is the state agency responsible for regulation of coastal shorelines.

The Department of Ecology prepares SMP guidelines and provides technical support and assistance to local governments. Local governments prepare SMPs to address local circumstances consistent with Department of Ecology guidelines. The Department of Ecology reviews and approves local SMPs upon finding consistency with the SMA and guidelines.

All shoreline uses and activities must be consistent with the SMA and requirements of the local SMP. Uses or activities identified in the SMP may require shoreline conditional use or variance permits. Only those actions defined as "substantial development" require a substantial development permit (SDP). Substantial development permits are approved by local governments. Certain federal actions trigger review for consistency with state CZM Program and local SMP requirements.

Substantial development permits are sent to the Department of Ecology, which may appeal the permit action to the Shoreline Hearings Board. Conditional use or variance permits are subject to review and approval by the Department of Ecology.

The SMA does not contain any references to geologic or tsunami hazards. Washington Administrative Code (WAC) Chapter 173-16, Shoreline Management Act Guidelines For Development of Master Programs, only mentions geologic hazards in the context of siting oil and gas facilities.

State Role

While state agencies may review and comment on draft comprehensive plans, comprehensive plans are not approved by a state agency**.** However, the Washington Department of Community, Trade, and Economic Development (DCTED) has adopted procedural criteria to assist local governments in the development of comprehensive plans. State agencies must comply with local comprehensive plans and development regulations (RCW 36.70A.103).

The Land Use Study Commission was created in 1995 to explore and eventually merge Washington's land use planning and environmental laws to encourage environmentally-responsible economic growth. The Commission was also charged to consider the effectiveness of state and local government efforts to consolidate and integrate the Growth Management Act, the State Environmental Policy Act, the Shoreline Management Act, and other land use, planning, environmental, and permitting laws.

In a report issued in December 1998, the Commission concluded that a consolidated land use code has the potential for many benefits. At this time, however, it stated there is not the consensus and funding necessary for its final development and adoption.

SUMMARY

Table 2-1, Comparison of Planning Requirements, provides a summary of state land use regulations, including hazard mitigation requirements based primarily on information published in 1998 by the Institute for Business and Home Safety. ‘Vertical consistency’ refers to required consistency of local plans with state plans. ‘Horizontal consistency’ refers to required consistency of local plans with each other.

Table 2-1. Comparison of Planning Requirements

	Statewide Planning Guidelines?	Vertical Consistency Required?	Horizontal Consistency Required?	State Specifies Elements of Comprehensive Plan?	Hazard Mitigation Element Required?
Alaska	No. Except for land use plans for coastal resource districts.	Management plans of coastal resource districts are required to undergo consistency review with plans of state agencies.	Management plans of coastal resource districts required to undergo consistency review with plans of coastal resource districts.	State specifies elements of coastal plans, and suggests elements for mandatory comprehensive plans of other communities.	Yes. For coastal plans. No. For other mandatory plans.
California	Yes	No. City or county must consult with state, but guidelines are advisory only.	No. State suggests but does not require that cities and counties refer plans to neighboring jurisdictions for comment.	Yes	Yes. As part of Safety Element.
Hawaii	Yes	No. Guidelines are advisory only.	No. State suggests but does not require.	No. State suggests but does not require elements.	No. State suggests but does not require.
Oregon	Yes	Yes. Local plans must be consistent with state planning goals.	No. State suggests but does not require.	Yes	Yes
Washington	Yes. For high-growth counties and cities.	Yes	Yes. Required of high-growth county/city plans but not of shoreline municipality plans.	Yes	Yes. For "Critical areas" which include "Geologically hazardous areas."

Sources:
Summary of State Land Use Planning Laws, Institute for Business and Home Safety, April 1998.
Mintier & Associates, 2000.